What are the benefits in relationship to the risks for seafood consumption?

Conclusion

Moderate, consistent evidence shows that health benefits derived from the consumption of a variety of cooked seafood in the US in amounts recommended by the Committee outweigh the risks associated with methyl mercury (MeHg) and persistent organic pollutants (POPs) exposure, even among women who may become or who are pregnant, nursing mothers, and children ages 12 and younger. Overall, consumers can safely eat at least 12oz of a variety of cooked seafood per week, provided they pay attention to local seafood advisories and limit their intake of large, predatory fish. Women who may become or who are pregnant, nursing mothers, and children ages 12 and younger can safely consume a variety of cooked seafood in amounts recommended by this Committee, while following Federal and local advisories.

Grade: Moderate

Overall strength of the available supporting evidence: Strong; Moderate; Limited; Expert Opinion Only; Grade not assignable For additional information regarding how to interpret grades, click here.

Evidence Summary Overview

A total of nine studies were reviewed regarding the benefits in relationship to the risks for seafood consumption. Two received positive quality ratings (one meta-analysis and one cross-sectional study) and seven received neutral quality ratings (three quantitative risk/benefit assessment studies, three cross-sectional studies one of which also included a risk/benefit analysis, and one systematic review). A report from the Institute of Medicine (IOM), Seafood Choices (2007), was used as evidence prior to 2006 to develop the conclusion.

Since the publication of the 2005 Dietary Guidelines Advisory Committee (DGAC) Report, five quantitative (Ginsberg and Toal, 2009; Guevel et al, 2008; Gochfeld and Burger, 2005; Sioen et al, 2008; Verger et al, 2008) and two qualitative (IOM, 2007; Mozaffarian, 2006) risk/benefit assessments have been published. These studies targeted the US (Ginsberg and Toal, 2009; Gochfeld and Burger, 2005; Mozaffarian and Rimm, 2006), French (Guevel et al, 2008; Verger et al, 2008) and Belgian (Sioen et al, 2008) populations. The two US quantitative benefit/risk analyses modeled neurodevelopmental and cardiovascular disease (CVD) benefits and risks associated with docosahexaenoic acid (DHA) and methylmercury (MeHg) in seafood (mostly fish), respectively (Ginsberg and Toal, 2009; Gochfeld an Burger, 2005). The French study based on the Quality-Adjusted Life Year (QALY) approach modeled neurodevelopmental benefits and risks associated with DHA and MeHg but did not include the function describing the potential harm of MeHg on cardiovascular health (Guevel et al, 2008). The Belgian study examined different levels of seafood intake in relationship to the tolerable weekly intake levels of MeHg and dioxin-like compounds (Sioen et al, 2008). Verger et al, (2008), the other French study, examined seafood intake thresholds based on omega-3 polyunsaturated fatty acid (n-3 PUFA) recommendations and the upper tolerable intake limits for dioxins and polychlorinated biphenyls (PCBs), a type of persistent organic pollutant (POP). The two qualitative analyses addressed benefit and risks on neurodevelopment and cardiovascular health attributed to DHA and MeHg. In addition, Mozaffarian and Rimm (2006) estimate the benefit/risk ratios based on n-3 PUFA benefits andPOPs exposure risks. Gochfeld and Burger (2005) found that the benefit threshold for neurodevelopmental and CVD outcomes appears to be at seafood intakes below the harm threshold associated with MeHg consumption.

Three of the studies (Dewailly et al, 2007; Mozaffarian and Rimm, 2006; Rawn et al, 2006) examined in this review suggest that POPs levels at current and recommended levels of seafood consumption in North America from commercially caught or farmed seafood are safe. Huang et al, (2006) note that concerns continue to be raised about the higher levels of POPs found in farmed vs. wild seafood, including salmon. Regarding this concern, Mozaffarian and Rimm (2006) documented strong benefit/risk ratios (range: 100 to 1,000-fold) associated with the consumption of wild or farmed salmon taking into account cardiovascular benefits associated withDHA consumption and excessive cancer rates attributed to potential exposure to POPs. Consistent with this finding, Verger et al, (2008) found that recommended intakes of n-3 PUFA can be met and even exceeded through eating seafood without going beyond POP's upper tolerable intake limits.

In summary, benefit/risk modeling studies indicate that if appropriate seafood choices are made, namely emphasizing consumption of seafood low in MeHg and POPs, consumers may be able to eat 12 ounces or more of a variety of seafood per week safely, although additional CVD benefits may not be obtained beyond 12 ounces (Mozaffarian and Rimm, 2006). Mozaffarian and Rimm (2006) is the only quantitative study that conducted benefit/risk assessments by seafood species consumed in the US (based on MeHg risk only). Ginsberg and Toal (2009) concluded that individuals can consume safely one six-ounce meal per day for seven out of the 16 seafood species modeled taking into account infant neurodevelopment and for nine of these species when modeling cardiovascular health.

Evidence Summary Paragraphs

Dewailly et al, 2007 (neutral quality), a cross-sectional analysis conducted in Canada, compared concentrations of key contaminants and the omega-3 fatty acids between farmed and wild salmon and trout, and balanced the risks and benefits from regularly consuming these species. Farmed samples (46 salmon, 37 trout) were obtained from supermarkets located in municipalities of the Province of Quebec, and wild samples (10 salmon, 10 trout) were obtained from fishermen of the Gaspe Peninsula and from various Canadian agencies. Concentrations of total mercury in fillets of farmed salmon were approximately threefold lower than wild salmon ($P<0.05$) and mean total polychlorinated biphenyls concentration in farmed salmon was approximately two-fold higher than wild salmon ($P<0.05$), but there were no differences observed between farmed and wild trout. Overall the concentrations of contaminants were low, such that the regular consumption of these fish would not cause tolerable daily intakes to be exceeded.

Ginsberg and Toal, 2009 (neutral quality), a risk/benefit analysis study developed a method to quantitatively analyze the net risk/benefit of individual fish species for adult cardiovascular and in-utero neurodevelopmental end points based on the methylmercury (MeHg) and omega-3 fatty acid content of those fish. A limited number of studies were selected from the literature to use in examining risk/benefit between specific fish species andCVD in adults, including coronary heart disease (CHD) mortality (fatal myocardial infarction [MI] and sudden death) or first MI, and neurodevelopment in six-month-old infants using the visual recognition memory (VRM) test (examined one study with 135 mother-infant pairs). Fish chosen for analysis were commonly available in Connecticut markets and for which MeHg and omega-3 fatty acids data were available. Study found that estimated omega-3 FA benefits outweigh MeHg risks for farmed salmon, herring and trout, but those benefits do not outweigh MeHg risk for swordfish and shark; a small net benefit is associated with consumption of flounder and canned light tuna and a small net risk is associated with consumption of canned white tuna and halibut. Study results were used to place fish into one of four meal frequency categories with the advice tentative due to limitations in underlying dose-response data. Separate advice for neurodevelopmental risk group vs. the cardiovascular risk group was recommended because of greater net benefit from fish consumption for the cardiovascular risk group. Individuals can consume safely one six-ounce meal per day for seven out of the 16 seafood species modeled taking into account infant neurodevelopment, and for nine of these species when modeling cardiovascular health. This study demonstrates a framework for risk/benefit analysis that can be used to develop categories of consumption advice ranging from "do not eat" to "unlimited," but unlimited may need to be tempered for certain fish because of other contaminants and end points (e.g., cancer risk).

Gochfeld and Burger, 2005 (positive quality), a meta-analysis of international studies, examined dose-response information for the benefits and harms of fish consumption, and presented a composite dose-response curve for methylmercury to elucidate the benefit/harm paradox. Thirteencohort studies on adult cardiovascular risks and fish consumption were identified, and seven studies provided data on threshold and asymptote for methylmercury in fish. Great disparities were found in the amount and distribution of both PUFA and contaminants in different fish species. The duration of pregnancy and birth weight improve at a benefit threshold of approximately 8-15g per day of maternal fish intake, and meta-analyses reveal adult cardiovascular benefits at approximately 7.5-22.5g per day (mid-point of 15g per day). Benefit asymptotes are above 45g per day and in some studies, exceed 100g per day. The benefit threshold for several endpoints (pregnancy duration and development and adult cardiovascular) consistently lie below the thresholds for harm from methylmercury. Using the US Environmental Protection Agency (USEPA) reference dose of 0.1µg/kg body weight per day as a methylmercury threshold, the fish intake threshold for harm equates to 27g per day (for common commercial fish averaging 0.23ppm methylmercury) to 65g per day (for fish averaging 0.1ppm methylmercury).

Guevel et al, 2008 (neutral quality), a risk-benefit/meta-analysis of five studies assessed the relative risk (RR) of methylmercury intake vs. the benefit of n-3 PUFA intake on CHD mortality, stroke mortality and morbidity and on prenatal cognitive development. Data used in this study was extracted from the CALIPSO study conducted among French coastal populations, representing approximately 226,000 respondents aged 34 years and older. This study used the Quality-Adjusted Life Year (QALY) approach to model neurodevelopmental benefits and risks associated withDHA and MeHg but did not include the function describing the potential harm of MeHg on cardiovascular health. The average eicosapentaenoic acid (EPA) + DHA intake of the CALIPSO population was 391mg per day, and the average MeHg exposure associated with fish consumption was 0.76µg/kg body weight per week. Results show that increasing fish consumption may have a beneficial impact on health, however, the confidence interval of the overall estimation has a negative lower bound, indicating that this increase in fish consumption may have a negative impact due to MeHg contamination.

Huang et al, 2006 (neutral quality) reported the results of a cross-sectional study done to determine the concentrations of contaminants in salmon, and to assess the cancer and non-cancer health risks associated with these contaminants. Farmed salmon samples (N=459) were purchased from 51 farms in eight farming regions in six nations. Wild salmon (N=135) was obtained from suppliers in Alaska, British Columbia and Oregon. Atlantic salmon filets (N=16) were also purchased from 16 North American and European cities. All samples were obtained between September 2001 and December 2002. Polychlorinated biphenyls (PCB), dioxin and pesticide concentrations for each salmon sample were measured usingUSEPA methods based on gas chromatographic high-resolution mass spectrometry. Polychlorinated biphenyls and dioxin levels were significantly higher in farmed and markets samples than in wild Pacific salmon. Pesticide content is significantly higher in farmed and retail market fish compared to wild salmon; though to a lesser degree than with the PCBs. Salmon from Europe had significantly higher contaminant levels than those from North America, while salmon from South America had the least contamination. Also, clear patterns of positive correlation were observed for all pairs of contaminants, such that if a fish was high in one contaminant, it is likely to be similarly high in all of the others. Overall, significant contaminant levels were found in both wild and farmed fish, with higher levels in farmed fish, and most of the contaminants found in farmed salmon are rated as "probable" (by the USEPA) or "possible" (by the International Agency for Research on Cancer, IARC) human carcinogens.

Mozaffarian and Rimm, 2006 (neutral quality), a systematic review including pooled and meta-analysis regarding fish consumption and health outcomes. The authors investigated:

1. Intake of fish or fish oil and cardiovascular risk
2. Effects of MeHg and fish oil on early neurodevelopment
3. Risks of MeHg for cardiovascular and neurologic outcomes in adults
4. Health risks of dioxins and polychlorinated biphenyls in fish, using primarily RCTs and prospective cohort studies.

When possible, meta-analyses were done to characterize benefits and risks most accurately. Modest consumption of fish (one to two servings per week), especially species higher in EPA and DHA, reduced risk of coronary death by 36% (95% CI, 20%-50%; P<0.001) and total mortality by 17% (95% CI, 0%-32%; P=0.046). Intake of 250mg per day of EPA and DHA was sufficient for primary prevention. Docosahexaenoic acid appears beneficial for, and low-level methylmercury may adversely affect, early neurodevelopment in infants. Authors recommended that women of childbearing age and lactating women should consume two seafood servings per week, limiting intake to selected fish species that are high in EPA+DHA and low in MeHg. Methylmercury may modestly counteract the cardiovascular benefits of EPA+DHA in fish. The authors conclude that based on the strength of the evidence and the potential magnitudes of effect, the benefits of fish intake exceed the potential risks. For women of childbearing age, benefits of modest fish intake, excepting a few selected species high in MeHg, also outweigh risks.

Rawn et al, 2006 (neutral quality) conducted a cross-sectional analysis to determine the PCB, polychlorinated dibenzodioxins (PCDD) and polychlorinated dibenzofurans (PCDF) content in fin and non-fin fish products (N=129) from the Canadian retail market in 2002. Market samples of fresh and salt water fish and shellfish (char, crab, mussels, oysters, salmon, shrimp, tilapia and trout) were purchased in Canada during the winter and spring of 2002. Farmed, wild, fresh, frozen, previously frozen and live samples were included. The majority of samples were farmed because of limited availability of wild fish or shellfish at the time of the study. Total PCB concentrations ranged from 42.3-45,100pg per gram whole weight and PCB concentrations were highest in salmon. There were no significant (NS) differences between farmed and wild fish in terms of PCB concentrations. The PCDD and PCDF concentrations ranged from below method detection limits to 8.23pg per gram whole weight. Lipid content was positively and significantly correlated to PCB concentrations (P<0.0001), but not to PCDD/PCDF concentrations (P=0.55). In all samples tested in the present study, contaminant levels were below the Canadian guideline values for fish and fish products, such that the exposure to PCBs and PCDD/PCDF as a result of fish and shellfish consumption is not at a level sufficient to pose a risk to human health.

Sioen et al, 2008 (neutral quality), a quantitative assessment/meta-analysis of a hypothetical scenario in Belgium, evaluated if the recommendation for long chain n-3 PUFAs can be obtained by fish consumption without exceeding the provisional tolerable weekly intake of methylmercury and the tolerable weekly intake of dioxin-like compounds. Data from the Pan-European SEAFOODplus consumer survey were used, which analyzed the seven most commonly consumed fish, and hypothetical groups were established to include three consumption patterns and three sub-scenarios for each consumption pattern including the frequency of consuming fish (once, twice or three times per week). A hypothetical population was used, including a sample of 600 individuals (300 men, 300 women), evenly distributed into four age groups (30-39 years, 40-49 years, 50-59 years, and 60-69 years). The Belgian recommendation for EPA + DHA (0.3% of energy intake) can be reached by consuming fatty fish a minimum of twice a week, or by varying between lean and fatty fish a minimum of three times a week; none of the scenarios would cause a methylmercury intake of toxicological concern. However, consuming fatty fish three times a week leads to an intake of potential toxicological concern, therefore, other food sources of EPA + DHA should be considered.

Verger et al, 2008 (positive quality), a cross-sectional study conducted in France, estimated the percentage of fish-eating French adults below and above the toxicological thresholds for dioxins and PCBs and the nutritional daily allowance for long-chain n-3 polyunsaturated fatty acids (LC n-3 PUFA). A total of 401 subjects (206 women and 195 men) identified in the CORAI STUDY), who all lived in households that included a woman of childbearing age and at least one child below age 15, completed food frequency diaries that were used to estimate their fish consumption, their intake of LC n-3 PUFA, and dietary exposure to POPs such as dioxins and PCBs. For these subjects, selected because of their consumption of fish, 60% achieved the nutritional recommendation for LC n-3 PUFA and 79% were exposed to total dioxins below the toxicological threshold of 14pg per kg body weight per week. A total of 41% of these subjects had an optimal balance between the risk and benefit of eating fish, because 19% were meeting the nutritional recommendation but exceeding the toxicological threshold, whereas 38% were exposed below the toxicological threshold but failed to reach the recommended intake of LC n-3 PUFA. The authors note results showing that meeting the nutritional requirements of 0.5mg per day of LC n-3 PUFA is compatible with respect to toxicological thresholds, while an intake higher than 1.5g per day is likely to lead to a dietary exposure above the provisional tolerable weekly intake for dioxins. Results show that recommended intakes of n-3 PUFA can be met and even exceeded through eating seafood without going beyond POP's upper tolerable intake limits.

View table in new window

Author, Year, Study Design, Class,	Population/Sample Description	Study Design/Variables/Intervention	Results/Risk-Benefit Ratio & Outcomes/Significanc	Limitations

Rating				
Dewailly et al 2007 Study Design: Cross-sectional Study Class: D Rating:	Farmed samples (46 salmon, 37 trout) obtained from supermarkets located in municipalities of the Province of Quebec and wild samples (10 salmon, 10 trout) obtained from fishermen of Gaspe Peninsula and from various Canadian agencies. Location: Canada.	Cross-sectional analysis comparing concentrations of key contaminants and the n-3FA between farmed and wild salmon and trout and balancing the risks/benefits from regularly consuming these species. Dependent Variables: Concentration of mercury, Polychlorinated bi-phenyl (PCB) congeners, Polychlorinated dioxins/furans (PCDD/Fs), total toxic equivalent (TEQ) concentration. Independent Variables: Wild vs. farmed salmon and Rainbow trout; Dietary intake of mercury, PCBs and PCDD/Fs.	Concentrations of total mercury in fillets of farmed salmon were ~three-fold ↓ than wild salmon ($P<0.05$) and mean total PCB concentration in farmed salmon was ~twofold ↑ than wild salmon ($P<0.05$), but NS differences observed between farmed and wild trout. Overall concentrations of contaminants were ↓, such that the regular consumption of these fish would not cause tolerable daily intakes to be exceeded.	Small number of samples; only 10 samples of wild fish studied.
Ginsberg GL and Toal BF, 2009 Study Design: Risk/benefit analysis Class: M Rating:	Five studies chosen to perform integrated risk/benefit analysis of effects of n-3FA and MeHg intake on adult CVD outcomes and infant neurodevelopment. For adult CVD risk/benefit analysis: Combined data across 20 studies for EPA-DHA intake vs. CHD mortality from one of the five studies. For neurodevelopmental risk/benefit analysis: Measured VRM in 135 mother-infant pairs.	Design: Risk/benefit analysis study developed method to quantitatively analyze net risk/benefit of individual fish species for adult cardiovascular and in-utero neurodevelopmental end-points based on the MeHg and n-3FA content of those fish. Dependent Variables: Adult CVD end-points (Adult fatal MI or sudden death, or adult first MI; Neurodevelopmental end-point (Visual recognition memory (VRM) score among six-month-old infants). Independent Variables: For adults CHD risk: mg n-3FA content of meal; number of fish meals per week; hair Hg content. For infant VRM: mg n-3FA content of meal; number of fish meals per week. (Intake of EPA + DHA as reflected in n-3FA content of 16 species of fish MeHg intake as reflected in hair and toenail MeHg content resulting from consumption of 16 species of fish)	Estimated n-3FA benefits outweigh MeHg risks for farmed salmon, herring, and trout, but those benefits do not outweigh MeHg risk for swordfish and shark. Small net benefit associated with consumption of flounder and canned light tuna and a small net risk associated with consumption of canned white tuna and halibut. Study results used to place fish in one of four meal frequency categories with advice tentative due to limitations in underlying dose-reponse data. Separate advice for neurodevelopmental risk group vs. the cardiovascular risk group was recommended because of ↑ net benefit from fish consumption for cardiovascular risk group. Study demonstrates	Assumptions made that n-3FA benefit requires consistent exposure over time and that no other fish were consumed other than one meal per week of the indicated species. Analysis only assessed two factors (i.e., only n-3FA and MeHg) regarding fish ingestion that may influence end-points of interest. Lack of examination of other nutrients and contaminants in fish and other end-points of concern creates uncertainty regarding overall health implications of fish consumption. Dose-response relationships for risks/benefits are supported by available data, but do contain uncertainties (e.g.,

			Study demonstrates framework for risk/benefit analysis that can be used to develop categories of consumption advice ranging from "do not eat" to "unlimited," but unlimited may need to be tempered for certain fish because of other contaminants and end-points (e.g., cancer risk).	other nutrients may have contributed to observed benefits) Did not separate out benefits from other nutrients in fish. Reported slope for Δ in RR per 100mg per day intake of EPA + DHA unadjusted for countervailing effect of MeHg may underestimate the true relationship or suggest a plateau in benefit that is an indication of MeHg toxicity. Saturation may be artificial due to ↑ effects of MeHg at ↑ fish ingestion rates and evidence of no saturation of benefits in some studies, analysis did not include a saturation function for the n-3FA benefit. Dose-response for MeHg effects on MI based on relationship between toenail mercury and MI ORS, which often overestimates CV benefit in terms of improved RR. More extensive data for both n-3FA and MeHg content of fish are needed to improve confidence and understand variability in this key input data. In VRM study, group that showed the MeHg effect was small (↑ hair mercury, ↓ fish intake, N=12); analyses were limited because each fish species assessed in isolation from consumption of any other fish.

				Analyses did not include variability in fish concentrations in n-3FA and MeHg, variability in toxicokinetics of MeHg, and variability in response functions for n-3 FA and MeHg.
Gochfeld and Burger 2005 Study Design: Meta-analysis Class: M Rating:	N=13 cohort studies on adult cardiovascular risks and fish consumption identified and seven studies provided data on threshold and asymptote for MeHg in fish. Location: International studies.	Examined dose-response information for benefits/harms of fish consumption and presented composite dose-response curve for MeHg to elucidate benefit/harm paradox. Dependent Variables: Developmental and adult cardiovascular benefits of fish consumption. Independent Variables: Fish consumption (usually by dietary recall in studies) One meal assumed to equal 8oz of fish (227g). [To estimate toxicity from MeHg concentration of fish: Nine types of fish most commonly available in New Jersey markets (not including canned tuna)]	Great disparities found in amount and distribution of both PUFAs and contaminants in different fish species. Duration of pregnancy and birth weight improve at a benefit threshold of ~eight to 15g per day of maternal fish intake and meta-analyses reveal adult cardiovascular benefits at ~7.5-22.5g per day (mid-point of 15g per day). Benefit asymptotes above 45g per day and in some studies, exceed 100g per day. Using the USEPA reference dose of 0.1µg/kg body weight per day as a MeHg threshold, fish intake threshold for harm equates to 27g per day (for common commercial fish averaging 0.23ppm MeHg) to 65g per day for fish averaging 0.1ppm MeHg).	None.
Guevel et al 2008 Study Design: Risk-Benefit / Meta-Analysis Class: M Rating:	Data used were extracted from the CALIPSO study conducted among French coastal populations, representing ~226,000 respondents aged ≥34 years. Location: France.	Design: Risk-benefit/meta-analysis of five studies published in the US. Assessed RR of MeHg intake vs. benefit of n-3PUFA intake on CHD mortality, stroke mortality and morbidity and on prenatal cognitive development. Dependent Variables: CHD mortality, stroke mortality, and	Average EPA + DHA intake of CALIPSO population was 391mg per day and average MeHg exposure associated with fish consumption was 0.76µg/kg body weight per week. ↑ fish consumption may have beneficial impact	Numerous theoretical assumptions made throughout the analyses, and limited generalizability to other populations.

		morbidity; Fetal neuronal development, in terms of IQ loss or gain. Independent Variables: Δ from medium to high n-3 PUFA intake.	on health, however, the CI of the overall estimation has a negative lower bound, indicating that this ↑ in fish consumption may have a negative impact due to MeHg contamination.	
Huang X et al 2006 Study Design: Cross-sectional study Class: D Rating:	N=459 Farmed salmon samples purchased from 51 farms in eight farming regions in six nations. Wild salmon (N=135) obtained from suppliers in Alaska, British Columbia and Oregon Atlantic salmon filets (N=16) purchased from 16 North American and European cities.	Design: PCB, dioxin and pesticide concentrations for each salmon sample measured using USEPA methods based on gas chromatographic high-resolution mass spectrometry. Dependent Variables: Dioxin, furan, total toxic equivalent, PCBs, organopesticide and toxaphene concentrations for each salmon sample. Independent Variables: Region of origin, retail market and wild vs. farmed status for each sample determined at time of purchase.	PCB and dioxin levels significantly ↑ in farmed and markets samples than in wild Pacific salmon. Pesticide content significantly ↑ in farmed and retail market fish compared to wild salmon. Salmon from Europe had significantly ↑ contaminant levels than those from North America, while salmon from South America had least contamination. Positive correlation observed for all contaminants, so if fish was ↑ in one contaminant, it was likely to be ↑ in others. Most of the contaminants found in farmed salmon are rated as "probable" (by USEPA) or "possible" (by IARC) human carcinogens.	None.
Mozaffarian D, Rimm EB 2006 Study Design: Meta-analysis or Systematic Review Class: M Rating:	Articles published through April 2006 were identified through MEDLINE, governmental reports, systematic reviews and meta-analyses. Included studies primarily evaluating risk in humans and focusing on evidence, when available, from RCTs and large prospective studies.	Outcomes collected included: Effect of intake of fish or fish oil on cardiovascular risk, effects of MeHg and fish oil on early neurodevelopment, risks of MeHg for cardiovascular and neurologic outcomes in adults and health risks of dioxins and PCBs in fish. Evidence for risks/benefits considered overall and among different at-risk populations. When possible, pooled or meta-analyses performed to	Modest consumption of fish (e.g., one to two servings per week), especially species higher in the n-3 FA EPA and DHA, ↓ risk of coronary death by 36% (95% CI, 20%-50%; P<0.001) and total mortality by 17% (95% CI, 0%-32%; P=0.046) and may favorably affect other clinical outcomes. Intake of 250mg per day	Per authors: Regarding evidence on MeHg and development, comparisons across studies are limited by heterogeneity of study designs (prospective vs. cross-sectional), mercury assessment methods, neurologic tests used, timing of assessment (infancy vs. childhood) and

		characterize effects most precisely.	of EPA and DHA appears sufficient for primary prevention. DHA appears beneficial for, and ↓-level MeHg may adversely affect, early neurodevelopment. Health effects of ↓-level MeHg in adults not clearly established; MeHg may modestly ↓ cardiovascular benefits of fish intake.	statistical methods. Some analyses also limited by multiple statistical testing or incomplete adjustment for other potential risk factors. Randomized trials to test effects of reducing ↓-level MeHg exposure during gestation have not been performed. Studies involving estimated cancer risks include based on animal-experimental data and limited studies in humans at ↑ doses.
Rawn DF et al 2006 Study Design: Cross-sectional study Class: D Rating:	N=129 samples of fish and shellfish obtained in Canada in 2002 (included farmed, wild, fresh, frozen, previously frozen and live samples). Location: Canada.	Design: PCB, PCDD and PCDF content determined for each sample using mass spectrometry. Dependent Variables: PCDD, PCB and PCDF content for each fish/shellfish sample Independent Variables: Fish species, processing factors (fresh, frozen) and source (wild, farmed) determined at time of purchase.	PCB content ranged from 42.3-45,100pg per g whole weight and PCB concentrations highest in salmon. NS differences between farmed and wild fish in terms of PCB content. PCDD and PCDF content ranged from below method detection limits to 8.23pg per g whole weight. Lipid content positively and significantly correlated to PCB concentrations ($P<0.0001$), but not to PCDD/PCDF concentrations ($P=0.55$). Contaminant levels in all samples below Canadian guideline values, so PCB and PCDD/PCDF exposure due to fish/shellfish intake not a risk to human health.	Origin of fish/shellfish samples not reported. Farmed and wild samples not available for every fish/shellfish tested. There were more farmed samples compared to wild.

Sioen et al 2008 Study Design: Quantitative Assessment / Meta-Analysis Class: M Rating:	A hypothetical population was used, including sample of 600 individuals (300 men, 300 women), evenly distributed into four age groups: • 30-39 years • 40-49 years • 50-59 years • 60-69 years. Location: Belgium.	Quantitative assessment/meta-analysis of a hypothetical scenario in Belgium, evaluated if recommendation for long chain n-3 PUFA can be obtained by fish consumption without exceeding the provisional tolerable weekly intake of MeHg and the tolerable weekly intake of dioxin-like compounds. Pan-European SEAFOOD plus consumer survey data were used [which analyzed seven most commonly consumed fish and hypothetical groups established to include three consumption patterns and three sub-scenarios for each consumption pattern including the frequency of consuming fish (once, twice or three times per week)]. Dependent Variables: Contaminants: MeHg; Dioxin-like PCB (dlPCB); dioxins plus furans (PCDD/F); total dioxin-like compounds (totTEQ). Independent Variables: Fish consumption of seven types of fish: Cod, Tuna, Alaska pollock, Plaice, Atlantic salmon, Herring, Mackerel and total lean fish and total fatty fish. Nutrients: EPA+DHA considered as one nutrient, long chain n-3 PUFA.	Belgian recommendation for EPA + DHA (0.3% of energy intake) can be reached by consuming fatty fish a minimum of twice a week, or by varying between lean and fatty fish a minimum of three times a week. None of the scenarios would cause a MeHg intake of toxicological concern. However, consuming fatty fish three times a week leads to intake of potential toxicological concern, therefore, other food sources of EPA + DHA should be considered.	Inclusion/exclusion criteria for data sources and references not described for hypothetical scenarios.
Verger P et al 2008 Study Design: Cross-sectional study Class: D Rating:	N=206 women and 195 men from 206 households met inclusion criteria (household had to include a woman of childbearing age and at least one child <age 15 years) and were accepted for study. Location: Nantes, France.	Design: Study estimated percentage of subjects below and above toxicological thresholds for dioxins and PCBs and attainment of nutritional daily allowance for LC n-3 PUFA among a sample of the French adults (identified in the CORAI STUDY) who were fish eaters. Dependent Variables: Estimated dietary exposure to dioxins and PCBs and estimated intake of LC n-3 PUFA.	For study subjects, selected because of their consumption of fish, 60% achieved the nutritional recommendation for LC n-3 PUFA and 79% were exposed to total dioxins below the toxicological threshold of 14pg per kg body weight per week. 41% of these subjects had an optimal balance between the risk and benefit of eating fish, because 19% were meeting the nutritional recommendation but exceeding the toxicological threshold, whereas 38% exposed	Authors noted some drawbacks in the data analysis: Estimations not included about the dietary exposure to pollutants other than dioxins and PCBs, such as MeHg. Uncertainty remains about possible combined effects of fish contaminants when exposure from each of them remains below the threshold for safety concerns.

			below the toxicological threshold but failed to reach recommended intake of LC n-3 PUFA. Authors note results showing that meeting the nutritional requirements of 0.5mg per day of LC n-3 PUFA is compatible with respect to toxicological thresholds, while an intake >1.5g per day is likely to lead to a dietary exposure above the provisional tolerable weekly intake for dioxins. Results show that recommended intakes of n-3PUFA can be met and even exceeded through eating seafood without going beyond POP's upper tolerable intake limits.	

Research Design and Implementation Rating Summary
For a summary of the Research Design and Implementation Rating results, click here.

Worksheets

Dewailly E, Ayotte P, Lucas M, Blanchet C. Risk and benefits from consuming salmon and trout: a Canadian perspective. *Food Chem Toxicol.* 2007 Aug;45(8):1343-8.

Ginsberg GL, Toal BF. Quantitative approach for incorporating methylmercury risks and omega-3 fatty acid benefits in developing species-specific fish consumption advice. *Environ Health Perspect.* 2009 Feb; 117: 267-275.

Gochfeld M, Burger J. Good fish/bad fish: a composite benefit-risk by dose curve. *Neurotoxicology.* 2005 Aug;26(4):511-20.

Guevel MR, Sirot V, Volatier JL, Leblanc JC. A risk-benefit analysis of French high fish consumption: a QALY approach. *Risk Anal.* 2008 Feb;28(1):37-48.

Huang X, Hites RA, Foran JA, Hamilton C, Knuth BA, Schwager SJ, Carpenter DO. Consumption advisories for salmon based on risk of cancer and noncancer health effects. Environ Res. 2006 Jun;101(2):263-74.

Mozaffarian D, Rimm EB. Fish intake, contaminants, and human health: Evaluating the risks and the benefits. *JAMA.* 2006 Oct 18; 296(15): 1,885-1,899.

Rawn DF, Forsyth DS, Ryan JJ, Breakell K, Verigin V, Nicolidakis H, Hayward S, Laffey P, Conacher HB. PCB, PCDD and PCDF residues in fin and non-fin fish products from the Canadian retail market 2002. Sci Total Environ. 2006 Apr 15;359(1-3):101-10.

Sioen I, De Henauw S, Verbeke W, Verdonck F, Willems JL, Van Camp J. Fish consumption is a safe solution to increase the intake of long-chain n-3 fatty acids. *Public Health Nutr.* 2008 Nov;11(11):1107-16.

Verger P, Khalfi N, Roy C, Blanchemanche S, Marette S, Roosen J. Balancing the risk of dioxins and polychlorinated biphenyls (PCBs) and the benefit of long-chain polyunsaturated fatty acids of the n-3 variety for French fish consumers in

western coastal areas. Food Addit Contam Part A Chem Anal Control Expo Risk Assess. 2008 Jun;25(6):765-71.